Readers' Forum

The Evolution of the Surgical Mask: Filtering Efficiency Versus Effectiveness

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ABSTRACT

When originally introduced for use at the turn of the century, the primary function of the surgical mask was to prevent the migration of microorganisms residing in the nose and mouth of members of the operating team to the open wound of the patient. As technology developed new materials and designs, their filtering efficiencies gradually improved. However, there is no standard test method for assessing that capability, and its influence on the rates of surgical-wound infection has yet to be demonstrated. Quite to the contrary, both in-vitro and in-vivo studies indicate that a mask may not be universally necessary in today's surgical environment (*Infect Control Hosp Epidemiol* 1997;18:49-57).

THE NEED FOR A MASK

The first study supporting the use of a mask in surgery was published by Mikulicz, a German physician, in 1897.[1] Its use was predicated on the work done by Flugge, a German clinician, who had demonstrated the presence of bacteria in droplets from the nose and mouth.[2]

The publication of Hamilton's study in 1905 focused on the transmission of communicable diseases and the importance of droplets of sputum in the dissemination of tuberculosis infection.[3] Having found that the mouth was a fruitful source of streptococcal infection, he recommended that a specially constructed (not described) "mouth guard" be worn. When the product was tested, it was found to hold back the sputum droplets almost completely (Figure 1).

Then in 1918, while engaged in preventing the spread of diphtheria, meningitis, pneumonia, etc, Weaver and his group introduced the practice of wearing gauze masks covering the nose and mouth when caring for patients.[4]

THE FIRST SPECIFICATION

During this early period, it was simply the use of the mask in surgery on which all the attention was directed. Prompted by the fact that their masks were being procured from several different sources, Huller and Colwell in 1918 observed that there were extreme variations in the number of layers of gauze of which they were made, as well as the qualities of the gauze itself.[5]

Following a series of tests, the group concluded that the amount of gauze placed in superimposed layers necessary to provide complete protection from those that were infected had to be the equivalent to a total of 300 threads per square inch. As for the size, they were to be 8-in long and 5-in wide. Thus, the first specification for the mask was developed.

THE MASK'S FILTERING EFFICIENCY

At the same time, Doust and Lyon examined the role of face masks on infections of the respiratory tract.[6] In so doing, they examined some of the com-

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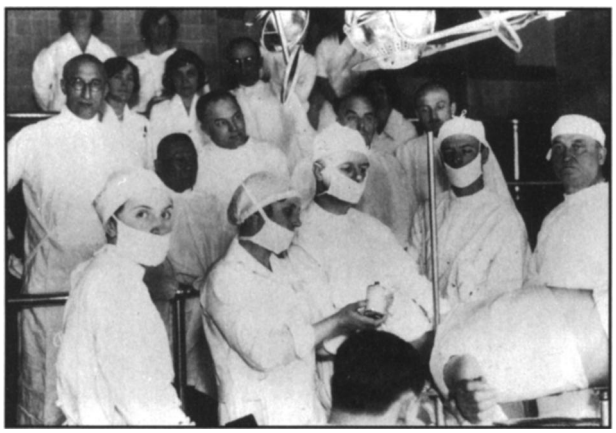

FIGURE 1. In the early days, masks only covered the mouth.[3] Reproduced with permission from the American Medical Association © 1905. (Hamilton A. Dissemination of streptococci through invisible sputum. *JAMA* 1905;44:1108-1111.)

mon types of masks in terms of their efficiency in preventing the dissemination of infectious material from the mouth during the acts of speaking or coughing. As the first study of its kind, the findings proved to quite revealing.

For example, speaking without a mask in ordinary conversational tone for 5 minutes projected relatively very few bacteria from the mouth and only for a distance of 1 to 2 ft. Speaking in a like manner for 30 minutes produced similar results. On the other hand, speaking without a mask in a loud tone for 5 minutes generated considerably more, with one organism projecting more than 3 ft.

It was during this same period (1919) that Weaver introduced a new dimension to the mask. Attention was now brought to the influence the face mask had on the distance traveled by mouth droplets that had been driven out in forced respiratory efforts.[7]

The results of these new tests indicated that the distance to which droplets were carried in the air depended principally on the force with which they were driven and that the small droplets could pass some distance, especially when carried by currents of air. The researchers also demonstrated that gauze could remove bacteria from the air when carried in a moist spray and that the efficiency of the gauze was in direct proportion to the density of the weave and the number of layers used.

Based on their experiences, the group adopted the use of a mask made of three layers of an absorbent gauze having a total thread count of 84 threads per square inch (44×40). They found the absorbent material preferable, because particles of mucus seemed to adhere to it more quickly and firmly.

THE FIRST IN-VIVO EXPERIENCE

An outbreak of influenza in California in 1919 brought about a challenging situation for compulsory use of the mask for the checking of epidemics. Despite the fact that use of the mask had been accepted cheerfully and universally by the public, their use proved to be a source of disappointment to the state's health officials, who found that they had no effect on the epidemic curve.[8]

However, following an array of tests, Kellogg and MacMillan concluded that (1) a mask's filtering capability could be varied by the number of layers and fineness of the mesh of the gauze; (2) when a sufficient degree of density was used to exercise a useful filtering influence, breathing was difficult and leakage took place around the edge(s) of the mask; and last, but not least, (3) masks had not been demonstrated to have a degree of efficiency that would warrant their compulsory application for the checking of epidemics.

THE "GERM-PROOF" MASK

Several years later (1930), a number of deaths following surgery prompted Walker to undertake a study designed to develop a method to determine the efficiency of the surgical mask that would enable it to be considered germ-proof.[9]

As an integral part of their investigation, his group surveyed 100 hospitals concerning the masks they were using. Of the 60 responses received, 42 were accompanied with samples. Of those 42, 22 were found to differ in design, the quality of the material, or the number of layers used. There were only seven masks that appeared to possess what were considered to be desirable attributes.

Their minimum standards for a mask to be considered germ-proof were that it would be constructed so as not to permit organisms to pass through it when the wearer, with both the nose and mouth covered, talked for 1 hour, with the area of the mask in front of the mouth moistened during the last 15 minutes.

Based on their experiences with the test, the requirements for the ideal mask were delineated as follows:

1. The cost should be low, and the mask should be one that could be used repeatedly, withstanding repeated launderings and sterilizations and still remaining germ-proof.
2. The mask should be comfortable, and not overly warm when worn to cover both nose and mouth, and should not cause fogging or condensation of moisture on lenses of those wearing glasses.

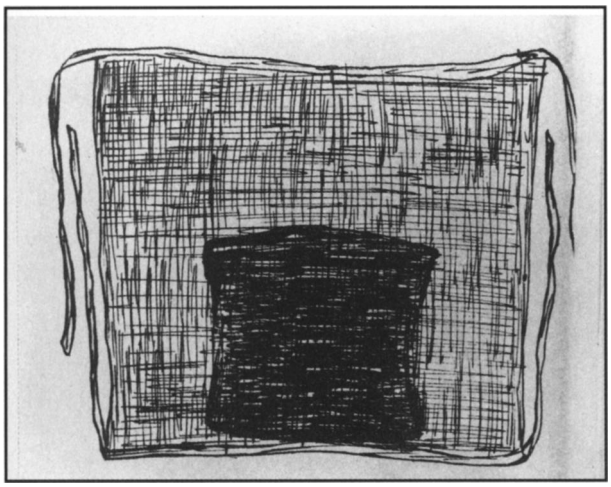

FIGURE 2. Walker's germ-proof mask consisted of a 6×6 piece of rubber (taken from a surgical glove) sandwiched between two layers of 10×10 gauze.[10] Reproduced with permission of the *Journal of the American College of Surgeons.* (Blatt ML, Dale ML. A bacteriological study of the efficiency of face masks. *Surg Gynecol Obstet* 1933;57:363-368.)

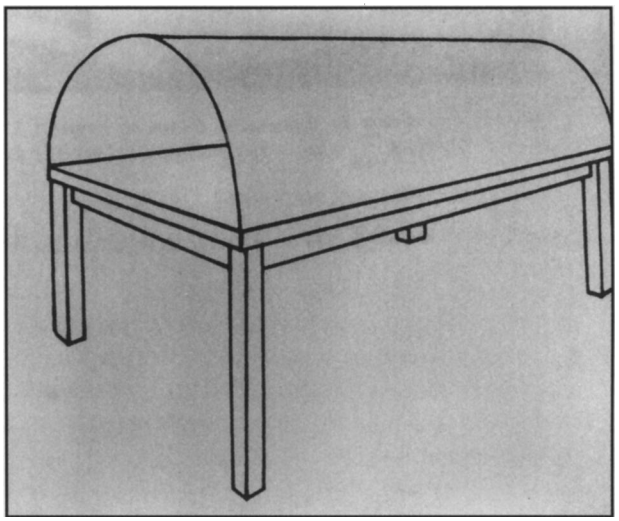

FIGURE 3. A dust-proof testing tunnel formed by a hood of cardboard, used in the 1930s to test the filtering efficiency of a surgical mask.[11] Reproduced with permission from the publisher (Waters EG. Adequate surgical masking: problem and solution. *Am J Surg* 1936;32:474-477) by Excerpte Medica Inc, © 1936.

3. The mask must not permit the passage of organisms when dry or moist during prolonged periods of conversation.

Despite the endless hours and exhaustive thought dedicated to all of the experiments, the group admitted not to being able to present the community with the ideal mask. However, they did come up with a design for one that included a 6-in square of rubber (taken from discarded surgical gloves) between two layers of 10-in squares of gauze (Figure 2). The edges of the gauze were turned in and stitched closed on three sides only. The fourth side was left open to facilitate replacement of the rubber. A small piece of aluminum was incorporated in the upper part of the mask and could be bent to fit the nose. Tests proved the mask to be germ-proof.

The introduction of the germ-proof concept prompted Blatt and Dale to assess the mask's efficiency some 3 years later (1933).[10] For this purpose, they constructed a dust-proof tunnel for use in their rigorous and unusual testing protocol (Figure 3). In the process, the effect of impregnating the materials with bacteriostatic substances (glycerine and aluminum subacetate) was examined. Although found to be more effective than the untreated masks, the sticky moisture and disagreeable odor caused by the additives made the masks uncomfortable.

Nevertheless, based on the comparative data, it was concluded that the commonly used six-layer gauze mask was both uncomfortable and ineffective bacteriologically. By comparison, they found a new cellophane-and-gauze (two layers) deflection-type mask to be inexpensive, easily put together, quite comfortable, effective, and nearly germ-proof. Confirming what had been demonstrated earlier, they similarly found that the number of organisms caught on plates directly in front of the person tested approached zero and that even the air discharged at the sides was practically sterile.

It was reasoned that the particles of moisture and mucus, being heavier than the air, continued forward by virtue of their momentum. They struck the mask and, due to their adhesive quality, were absorbed on the inner layer of gauze.

It should be noted that an integral part of assessing the mask's efficiency included monitoring the distance the expelled contaminants traveled. The greatest number were recovered on plates held 2 in from the mouth, followed by those 1, 3, and 5 ft away. The number of colonies that developed diminished as the distance increased. On the other hand, it was reasoned that droplets of the low-momentum variety could infect or contaminate the front of the surgeon's sterile gown and gloves, and thereby be transmitted to the patient by direct contact.

Thus, it again was concluded that a mask's filtering efficiency was contingent not only on the materials of which it was made but on its design and construction as well.

Despite the attention being directed at surgical masks, they still were not being used commonly during this period of their development. It generally was believed that there was no room for improvement in the operating room technique that had been handed down for several decades, and that excellent results were being achieved in wound healing. Arguments

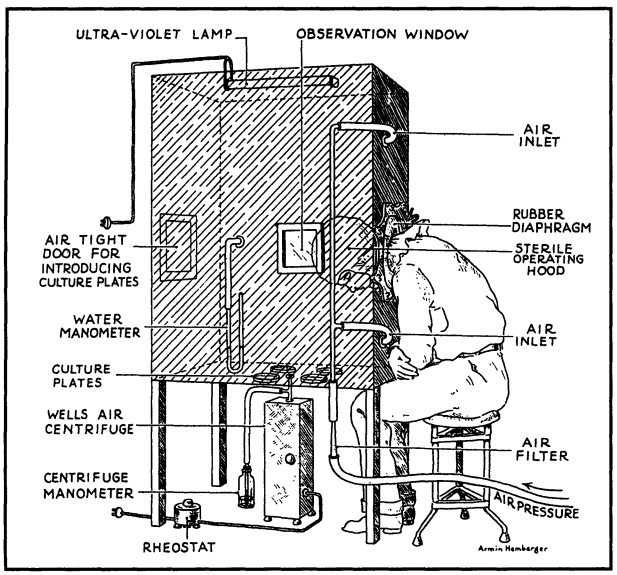

FIGURE 4. An airtight chamber developed by Hirshfield and Laube and used in their 1941 study.[13] Reproduced with permission from Mosby-Year Book, Inc, St. Louis, MO. (Hirshfield JW, Laube PJ. Surgical masks, an experimental study. *Surgery*, 1941;9:720-730.)

supporting the need for the surgical mask still virtually all had been predicated on its effectiveness as a bacterial filter as opposed to the efficacy of its use.

THE ERA OF NEW MATERIALS AND DESIGNS

The first change in the basic material, as well as the item's design, was introduced by Waters in 1935.[11]

With the objective of fulfilling the ideal performance requirements, the goal was to use an impervious material that completely blocked the mouth, chin, and nostrils; fit well over the nose, to prevent fogging of glasses; and was designed to deflect breath spray away from the wound. The new mask was made of a transparent, impermeable, lightweight, noncombustible substance, a cellulose derivative called "plastecele." The upper edge was "wedged" with a pliable aluminum band that could be bent to fit the shape of the nose. The part coming under the chin was shaped to catch perspiration drops. The mask was secured by ear pieces or cotton tapes that were tied around the head in the usual manner. Tests indicated that, when worn, most of the inspired air entered from about the chin, while most of the expired air was deflected backward past the cheeks and ears.

In 1938, Arnold[12] once again directed the focus back to filtering bacteria from the air expired from the nose and mouth rather than deflecting bacteria from the operative field. A material consisting of a combination of cotton and wood cellulose in the form of a creped wadding called "cellucotton" was found to be most effective. These tests also demonstrated that the greatest source of oral bacterial flora arose during loud talking and that the bacteria either escaped or were deflected above the mask lateral to and on each side of the nose. This was interpreted to mean that covering of the nose with an impermeable material deflected the expired air all around the edges of the mask and that the atmospheric pollution was the same as if no mask were worn.

Perhaps the most significant study published prior to World War II was that in which Hirshfield and Laube reported on the results of a series of experiments designed to test the efficiency of the masks themselves.[13] Based on what the researchers believed to be a shortcoming in the work done by their predecessors, they concluded that assessing a mask's filtering efficiency should be planned to record its ability to prevent the passage of droplets, as well as droplet nuclei. Utilizing a specially designed airtight chamber (Figure 4), the investigators tested a variety of commonly used surgical masks.

The researchers concluded that the use of conventional surgical masks was grossly inadequate, because they allowed large numbers of organisms to escape through or around them. This was attributable to the inability to construct a mask capable of preventing passage of all bacteria without making it so resistant to the passage of air that breathing through it would be arduous and the difficulty to fit a mask to the face in such a way that air did not escape around it.

THE POST-WORLD WAR II ERA

For a period of some 20 years, beginning with World War II, there was little work done in either the development or the efficacy of the surgical mask, and many institutions simply continued to use the comparatively inefficient mask made of coarse, absorbent gauze.

Nevertheless, by this time, surgical masks were viewed as being valuable for shielding the patient's wound from pathogenic bacteria from the surgeon's mouth and nose. It was felt that the mask could do this either by filtering bacteria from the air passing through it or by being impervious and deflecting the expired air so that it traveled behind the head. Although the deflection-type masks had been proven earlier to be effective in preventing bacterial penetration, they did not contribute to a reduction in the total bacterial count in the room. Therefore, the filter-type mask was considered preferable.

NEW MATERIALS AND DESIGNS

In 1958, Kiser and Hitchcock disclosed the availability of an entirely new type of mask. In addition to featuring wing-like cheek pieces designed to deflect exhaled air posteriorly, it also was made of a

new material—a flexible polyvinyl plastic.[14] To trap moisture, a replaceable cotton and wool fiber insert was incorporated in its construction in a manner conducive to its being changed after each case. After assessing the mask's suitability for use, the group found it objectionable for a number of reasons, the major one being that the wearer had to speak very loudly to make himself heard.

The following year, a renowned team of English clinical investigators, headed by Shooter, reported the results of their examination of masks made of three different types of materials and in three different designs.[15] The first mask was a basket-shaped filtration-type mask that fit fairly snugly over the nose and chin and was made of four layers of cotton gauze. Each layer of gauze had a thread count of 92 threads per square inch (46 each in warp and fill).

The second mask was a tail-type, or deflection, design made of a "double thickness of a closely woven cambric" with a piece of paper inserted between the layers. A tail of the cambric was attached to the bottom of the mask and ultimately was tucked under the operating room gown. The fit over the cheeks was loose.

The last mask was another deflection design made of paper, with the intent of being worn once and then discarded. It consisted of an outer and inner layer of paper that completely enveloped a pad of cellulose wadding. It covered the nose, mouth, and chin. Like the tail-type, it also fit loosely around the cheeks.

The researchers found that all three masks were able to protect the area in front of the mouth from many of the wearer's mouth and nose organisms. They also found, as had others, that increasing the thickness of the mask or improving the fit could lead to a point at which it would become difficult to breathe.

Perhaps the most noteworthy of their observations was made possible by their unique testing apparatus, which indicated that, with the deflection type masks, it seemed probable that deflected expired air inevitably would carry some of the shed bacteria behind the head. This may well have accounted for the experiences reported earlier by others, who had not considered the deflective-type mask acceptable for use, because it did not reduce the total count of bacteria found in the room.

The researchers also observed that the practice of lowering the mask around the neck was accompanied by the risk of contaminating both its outer and inner surfaces. For that reason, they suggested that, if a fresh mask could not be made available for every situation, the hands should be washed each time the soiled mask was touched.

In their 1960 state-of-the-art review of surgical masks,[16] Rockwood and O'Donoghue concluded among other things that (1) the mask should be worn by all members of the operating personnel, as well as by all persons entering the operating room; (2) the mask should cover both the mouth and nose at all times; (3) a moist mask should be discarded regardless of the length of time it has been used; (4) the mask should be changed after each case; (5) a filter-type surgical mask, under ordinary circumstances, could be worn safely for 3 hours; (6) the filter-type mask was the most efficient and should be used; and (7) the filter-type mask could be used with the plastic mask reported on earlier by Kiser-Hitchcock.[14] Perhaps the most noteworthy of their conclusions was that the "doors and windows should be kept closed to prevent drafts from stirring up settled bacteria in an operating suite."

QUANTITATIVE FILTERING EFFICIENCY

Up to this point, although a considerable amount of work had been done to assess the filtering efficiency of the surgical mask, relatively little had been done in terms of measuring the quantitative bacterial contribution of nasopharyngeal expirations to the atmospheric environment.

Most of the earlier studies used agar plates or glass slides that were positioned at various distances in front of and below the source of droplets and other particles that either settled or impinged on them. One of the shortcomings of these techniques was that they failed to measure the very small droplet nuclei that were not projected any appreciable distance, due to their low kinetic energy.

However, the development of the Andersen sampler in 1958 now made it possible to collect airborne particles in several categories of decreasing particle size. Information could be obtained regarding (1) the total contribution of orally expelled bacteriologic contaminants in known volumes of air; (2) the relative proportion of these contaminants associated with different size particles; and (3) the relative efficiency of the face mask against the organisms associated with different categories of particle size. With these objectives and the goal of advancing the test methodology, Greene and Vesley designed a testing chamber to best accommodate the new sampling device (Figure 5). They reported the results of their tests in 1962[17] and concluded that so-called mask efficiencies had little value in themselves, unless complete control of the environment and specific knowledge of particle-size association could be provided.

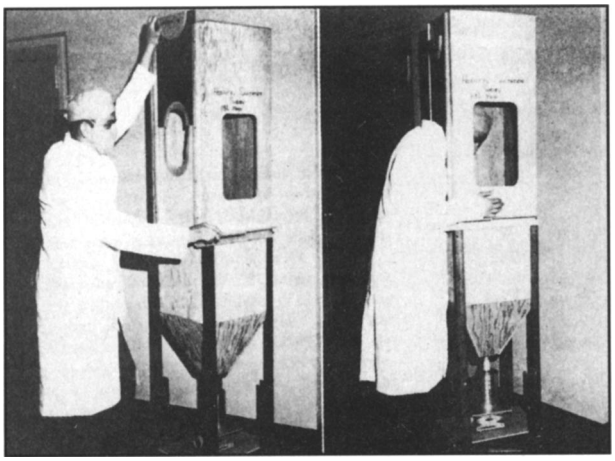

FIGURE 5. The Greene and Vesley sampling chamber (1962). Subject preparing to enter sampling chamber (left). Sampling chamber in use (right).[18] Reproduced with permission from Lippincott-Raven Publishers, Philadelphia, PA. (Ford CR, Peterson DE. The efficiency of surgical face mask. *p* 1963;106:954-957.)

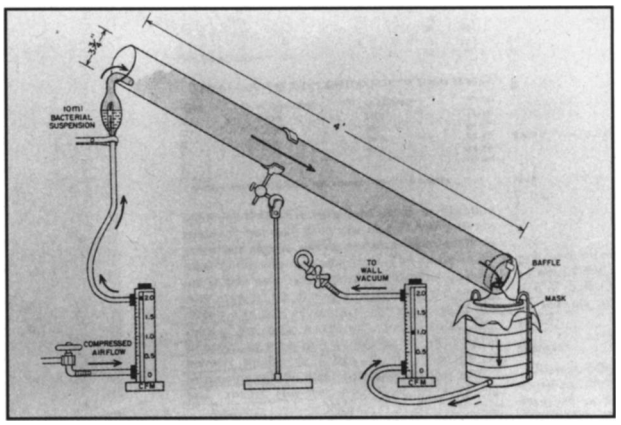

FIGURE 6. Sampling system used by Dineen in 1971 to measure the microbial filtration capability of surgical masks.[21] Reproduced with permission from the *Journal of the American College of Surgeons*. (Dineen P. Microbial filtration by surgical masks. *Surg Gynecol Obstet* 1971;33:812-814.)

Still faced with concern with the inefficiency of masks and the problem of discomfort associated with the nonfiltering or deflecting type of masks, Ford and Peterson introduced a new type of material and a new testing device in 1963.[18] Rather than testing masks while worn by humans, the test method was designed specifically to examine the filtering efficiency of the material of which the mask was made and used the Andersen air sampler in conjunction with a compressed-air source. One of the masks examined was made of spun glass and, like a number of others, was intended to be used one time only.

The following year, another new type of a controlled environmental testing device was used by Nicholes in evaluating a variety of mask materials on a comparative basis.[19] The Andersen sampler again was used to discriminate the size of the aerosol and viable particles.

It was concluded that masks manufactured from fine glass-fiber mats having a thickness of 1.5 to 2 mm could remove from 96% to 98% of the bacteria or viruses from an aerosol if shaped (designed) to enlarge the total air-diffusion area.

By 1967, the popularity of the first disposable mask made of a glass-fiber mat material was such that several others were introduced. These developments called for another evaluation to ascertain which material provided the maximum level of protection for the patient.

Madsen and Madsen began new tests[20] using the Andersen air sampler and the collecting chamber designed by Greene and Vesley. However, rather than testing with humans, the group used an artificial head (mannequin) having a rigid nose bridge and soft cheeks. Inasmuch as their initial tests demonstrated each of the disposable masks to be far superior to those made of five-ply gauze, only those made of the single-use materials were examined.

The efficiency of the different masks was expressed as the percentage of bacteria retained by the mask as compared to a control run in which the mannequin did not wear a mask. The setup was said to closely resemble that of a surgeon bent over a patient in the operating room, with intermittent simulated coughs or sneezes while wearing a mask.

The relative efficiency of the different masks was found to be, in descending order, polypropylene fibers, polyester-rayon fibers, glass-fiber mats, and cellulose (paper).

In addition to filtering efficiency of the materials used in surgical masks, there were several other questions to be answered regarding their effectiveness. For example, there was the length of time a mask could be used effectively and whether the masks should be changed at certain fixed periods, because they became inefficient when wet. These issues were addressed by Dineen in 1971.[21]

Again, the Andersen air sampler was used in conjunction with a cloud chamber (Figure 6). Dineen found that prolonged use and moistening of the more efficient masks did *not* impair their ability to filter, contrary to general belief.

An important and disconcerting finding was that there were wide variations in the filtering efficiencies of the masks, not only from one manufacturer to another, but, in certain instances, from mask to mask from the same manufacturer.

In 1975, Quesnel reported a study on the filtering efficiency of five different types of surgical masks of varying design and composition.[22] The Andersen

sampler and a testing chamber similar to that designed earlier by Greene and Vesley were used to collect and size contaminated particles escaping through or around the mask while the wearer was speaking. The data indicated that the gross efficiency of all the masks was high, but that three proved to be distinctly better at small-particle filtration than the other two. The difference in efficiency between the best and worst was significant.

In 1983, Shah, Crompton, and Vickers used a unique testing method designed to demonstrate photographically the manner in which particles were spread when a person coughed.[23]

It was found that use of a filtration-type mask resulted in small particles that remained suspended in the air and were unlikely to fall within a short distance from their source. Thus, with a properly fitted mask, the risk of infection from this source would be unlikely, especially in a room equipped with a proper ventilation system.

However, what the photographs also clearly demonstrated was that, if a person wearing a mask had to cough or sneeze, it was better to face the wound and *not* turn to one side, as most people instinctively do!

That same year, Vesley, Langholtz, and Lauer reported a newly designed mask made of a polymeric microfiber material and indicated its filtering efficiency as being significantly higher than 95%.[24] Sampling was done in a test chamber similar to the one developed earlier by Greene and Vesley. In addition to enumerating microbial particles with an Andersen sampler, total particles were quantified with a laser spectrometer. By so doing, the mask's efficiency was evaluated by its ability to retain both viable and nonviable particles.

THE MASK TODAY

The emphasis in mask development has been the concern for protecting the patient during surgery from the members of the surgical team. Consequently, efforts to improve the surgical mask, as seen by this chronological review, historically have been focused on its filtering efficiency. However, because no single standard method has been adopted universally for determining that attribute, claims reported by different sources are not always comparable, because the test methods may not be the same.[25,26]

Even with high filtering efficiency, some exhaled air will escape unfiltered around its edges, the amount depending on how well the mask fits. Because of this edge leakage, which can be as low as 5% or as high as 40%, a mask that is reported as being 99.9% effective is essentially only 95% or less effective. In other words, the mask is only as good as its fit. As the mask becomes wet from the exhalation of moist air, the resistance to air flow through it may increase, resulting in increased air leakage around the edges. It should be noted that popular in-vitro tests do not consider either edge leakage or the effect that prolonged use might have on edge leakage. Not to be overlooked is the fact that tests for these high-efficiency masks are conducted in a highly controlled, vacuum-like environment, quite unlike today's in-vivo conditions in which there are 20 to 25 air changes per hour.

Notwithstanding, the key question is the effect of all the improvements that have been made in masks as we know them today. Have they contributed to a reduction in the incidence of surgical-wound infection? Obviously, these improvements have increased their cost. Should the cost-effectiveness of a mask be predicated on its filtering efficiency or its theoretical effectiveness?

Two extensive in-vitro studies have been published, the first by Orr in 1981[27] and the more recent by Tunevall in 1991,[28] that indicate that the wearing of a mask does not influence the incidence of surgical-wound infection. In addition, there are studies by Ritter et al in 1971,[29] by Mitchell and Hunt in 1991,[30] and most recently by Hubble et al in 1996[31] that call into question the standard practice of requiring all personnel in the operating room, as well as those entering the surgical area, to wear a mask.

Furthermore, today there is reason for concern for the role of the surgical mask in protecting the healthcare worker from the patient and the hazards associated with the transmission of bloodborne pathogens. The Occupational Safety and Health Administration's Bloodborne Hazard Standard[32] identifies the surgical mask, in addition to a face shield and eye protection, as personal protective equipment to be worn in these exposure situations. In that capacity, the mask has acquired an additional function of resisting liquid penetration. Despite its new purpose, White and Lynch's recently published comprehensive multicenter study of more than 8,500 surgical procedures indicates that some 26% of all the blood contacts occurred on the face and neck.[33]

The results of another recent study indicate that, whereas contact of blood with mucous membranes or eyes occurred in 135 (4%) of 3,397 surgeon-procedures, no blood contacts were reported for the 117 surgeon-procedures in which face shields were worn ($P<.05$).[34]

It has been suggested that the mask perhaps could be replaced by what has been described as a "splash shield."[35,36] Our review suggests there is every reason to believe that an item of this nature,

rather than the conventional type of surgical mask, could be used safely by those personnel in the immediate area of the sterile field during general surgery. The shield would protect the patient by deflecting the air expelled by the wearer behind the head. Although the deflection-type masks historically had been found to be most effective in terms of protecting the patient,[5,8,10-12,15] they were not looked on favorably, because they did not reduce the total count of bacteria found in the room. Today, however, these droplets and particles would be moved to the periphery by the high-efficiency particulate air filtered air circulatory system. Wearing only a splash shield certainly would be more comfortable and would relieve any difficulties that may be experienced in breathing.

CONCLUSION

The historic contributions of asepsis have been enormous. Diligent adherence to aseptic practices had a dramatic influence on the advance of surgical science. However, because aseptic techniques cannot reduce endogenous flora or contamination already acquired in traumatic wounds, it has become more and more difficult to correlate infections with bacterial fallout in the operating room.

The use of the surgical mask originally was introduced as a standard of practice a century ago and subsequently supported by the results of Meleny's 1926 study, in which he indicated that having all attendant personnel wear masks reduced infection in clean wounds to a minimum.[37] At the time, its use seemed reasonable, and the practice simply was passed along on that basis. However, in his subsequent 9-year prospective study, Meleny reported the rate of infection to be closer to 15% rather than the 2% to 5% range that had been anticipated.[38] Indeed, I am not aware of any studies that conclusively demonstrate the effectiveness of the surgical mask in terms of reducing surgical-wound infection.

It has been said that the use of masks in today's surgical environment "reveals great variation in their application. For some, great care is taken to assure that the mask is tied loosely enough to allow the wearer to breathe around the mask. Some fail to secure the area at the nose and breathe over the mask."[39] Although the theories supporting the need for a surgical mask obviously are being violated, the use of masks seems to have been perpetuated by the "that's the way we've always done it" syndrome. Perhaps the time has come to address this question anew.

REFERENCES

1. Mikulicz J. Das operieren in steriliserten zwirnhandschuren und mit mundbinde. *Zentralbl Chir* 1897;24:713-717.
2. Flugge C. Uber luftinfection. *Z Hyg Infektionskr* 1897;25:179-224.
3. Hamilton A. Dissemination of streptococci through invisible sputum. *JAMA* 1905;44:1100-1111.
4. Weaver GH. The value of the face mask and other measures. *JAMA* 1918:76-78.
5. Huller DA, Colwell RC. The protective qualities of the gauze face mask. *JAMA* 1918;71:1213-1215.
6. Doust BC, Lyon AB. Face masks in infections of the respiratory tract. *JAMA* 1918;71:1216-1219.
7. Weaver GH. Droplet infection and its prevention by the face mask. *J Infect Dis* 1919;24:218-230.
8. Kellogg WH, MacMillan G. An experimental study of the efficiency of gauze face masks. *Am J Public Health* 1920;X:34-42.
9. Walker IJ. How can we determine the efficiency of surgical masks? *Surg Gynecol Obstet* 1930;50:266-270.
10. Blatt ML, Dale ML. A bacteriological study of the efficiency of face masks. *Surg Gynecol Obstet* 1933;57:363-368.
11. Waters EG. Adequate surgical masking: problem and solution. *Am J Surg* 1936;32:474-477.
12. Arnold L. A new surgical mask. *Arch Surg* 1938;37:1008-1016.
13. Hirshfield JW, Laube PJ. Surgical masks, an experimental study. *Surgery* 1941;9:720-730.
14. Kiser JC, Hitchcock CR. Comparative studies with a new plastic surgical mask. *Surgery* 1958;44:936.
15. Shooter RA, Smith MA, Hunter CJW. A study of surgical masks. *Br J Surg* 1959;203:246-249.
16. Rockwood CA, O'Donoghue DH. The surgical mask: its development, usage and efficiency. *Arch Surg* 1960;80:963-971.
17. Greene VW, Vesley D. Method for evaluating effectiveness of surgical masks. *J Bacteriol* 1962;83:663-667.
18. Ford CR, Peterson DE. The efficiency of surgical face masks. *Am J Surg Pathol* 1963;106:954-957.
19. Nicholes PS. Comparative evaluation of a new surgical mask medium. *Surg Gynecol Obstet* 1964;118:579-583.
20. Madsen PO, Madsen RE. A study of surgical masks. *Am J Surg.* 1967;114:431-435.
21. Dineen P. Microbial filtration by surgical masks. *Surg Gynecol Obstet* 1971;33:812-814.
22. Quesnel LB. The efficiency of surgical masks of varying design and composition. *Br J Surg* 1975;62:936-940.
23. Shah M, Crompton P, Vickers MDA. The efficiency of face masks. *Ann R Coll Surg Engl* 1983;65:380-381.
24. Vesley D, Langholtz AC, Lauer JL. Clinical implications of surgical mask retention efficiency for viable and total particles. *Infections in Surgery* 1983:531-536.
25. Davis WT. Filtration efficiency of surgical face masks: the need for meaningful standards. *Am J Infect Control* 1991;19:16-18.
26. Weber A, Willeke K, Marchioni R, et al. Aerosol penetration and leakage characteristics of masks used in the healthcare industry. *Am J Infect Control* 1993;21:167-173.
27. Orr NWM. Is a mask necessary in the operating theater? *Ann R Coll Surg Engl* 1981;63:390-392.
28. Tunevall TG. Postoperative wound infections and surgical face masks: a controlled study. *World J Surg* 1991;15:383-387.
29. Ritter MA, Eitzen H, French ML, Hart JB. The operating room environment as affected by people and the surgical face mask. *Clin Orthop* 1975;111:147-150.
30. Mitchell NJ, Hunt S. Surgical face masks in modern operating rooms—a costly and unnecessary ritual? *J Hosp Infect* 1991;18:238-242.
31. Hubble MJ, Weale AE, Perez JV, Bowleer KE, MacGowan AP, Bannister GC. Clothing in laminar flow operating theaters. *J Hosp Infect* 1996;32:1-7.
32. US Department of Labor, Occupational Safety and Health Administration. Occupational exposure to bloodborne pathogens: final rule. *Federal Register* December 6, 1991; 56:64177.
33. White MC, Lynch P. Blood contact and exposures among operating room personnel: a multicenter study. *Am J Infect Control* 1993;21:243-248.
34. Tokars JI, Culver DH, Mendelson MH, et al. Skin and mucous membrane contacts with blood during surgical procedures:

risk and prevention. *Infect Control Hosp Epidemiol* 1995; 16:703-711.
35. Beck WC. The surgical mask: another 'sacred cow'? *AORN J* 1992;55:955-957.
36. Beck WC. The surgical mask. *The Guthrie Journal* 1993;62:97-98.
37. Meleny FL, Stevens FA. Postoperative haemolytic *Streptococcus* wound infections and their relation to haemolytic *Streptococcus* carriers among the operating personnel. *Surg Gynecol Obstet* 1926;43:338-342.
38. Meleny FL. Infection in clean operative wounds: a nine-year study. *Surg Gynecol Obstet* 1935;60:264-275.
39. Koch F. Perspectives in surgical attire. *Infect Control Steril Tech* 1996;2:15-17.

Perinatal AIDS Declines

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As of September 30, 1996, a total of 566,002 AIDS cases among children were reported in the United States, including 7,472 cases among children aged <13 years. The majority of these cases acquired their HIV infection perinatally from their mothers. From 1992 to 1995, the estimated annual number of perinatally acquired AIDS cases declined 27% from 905 to 663. The CDC has commented that this decline in perinatal transmission probably reflects the effect of perinatal zidovudine therapy and that increasing proportions of women may be accepting voluntary prenatal HIV testing and using zidovudine (ZDV) to prevent perinatal transmission. In 1994, results of clinical trials demonstrating effective therapy for reducing perinatal HIV transmission indicated a two-thirds decrease in such transmission associated with ZDV for HIV-infected pregnant women and their newborns. The Public Health Service issued recommendations in 1994 for ZDV treatment to reduce perinatal HIV transmission, and in 1985 for routine HIV counseling and testing for all pregnant women in the United States. Unfortunately, the ZDV regimen is not an affordable prevention strategy in many countries where HIV prevalence rates are highest. Worldwide, an estimated 8.8 million women and 800,000 children have HIV infection; most of these persons reside in sub-Sahara Africa where resources are limited. Because ZDV treatment is not universally effective in preventing transmission nor is it always available, primary prevention of HIV infection among children will continue to require preventing new HIV infection among women in all countries.

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